Aquatic Angiosperms in Coastal Saline Lagoons of New South Wales. I. The Vegetation of Lake Macquarie

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The distribution and relative abundance of the four aquatic angiosperms in Lake Macquarie have been mapped. The seagrasses occupied an estimated 14.17km^2 or 12.3% of the lake surface area with *Zostera capricorni* (11.57km^2) and *Halophila ovalis* (5.59km^2) most widespread. There were some 2.01km^2 of *Posidonia australis* in the central lake region nearest the ocean entrance. The halotolerant *Ruppia megacarpa* was found in small amounts, and only in Chain Valley Bay.

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INTRODUCTION

Barrier estuaries or estuarine lagoons are characteristic of much of the south-east Australian coast (Barnes, 1980). These barrier estuaries range in size from large estuaries such as Wallis Lake and Lake Macquarie, which are over 100km^2, to small estuaries on the south coast e.g. Wallaga, Merimbula and Pambula Lakes. All are characterized by narrow, elongated entrance channels with broad tidal and backbarrier sand flats (Roy, 1984). Away from these active channels the lakes are shallow, low-energy environments with the margins often densely covered by seagrasses.

Three of these barrier estuary systems (Lake Illawarra just south of Wollongong and Lake Macquarie and Tuggerah Lakes on the N.S.W. Central Coast) are of special interest. These lakes all support some commercial fishing and prawning, but are in areas of rapid urbanization with increasing recreational use. Proximity to major population centres and coal deposits has made these lakes suitable sites for steam-generating power stations (Fig. 1). All of these power stations use steam-driven generating units and lake water is continuously drawn from an inlet channel to cool the condensers.

This paper is part of a series reporting the results of a long-term study on the aquatic vegetation in the Central Coast lagoons. An introductory paper on *Zostera capricorni* in Illawarra Lake has already been published (Harris *et al.*, 1980). The broad aim of these studies is to provide detailed qualitative and quantitative data on the aquatic vegetation in these lakes, to monitor long term changes, and to assess the effects of cooling water discharges from the power stations.

LAKE MACQUARIE

Lake Macquarie (Fig. 1) is a large barrier estuary some 90km north of Sydney, and just south of the industrial city of Newcastle. The lake has a surface area of 110km^2 and an irregular foreshore of some 166km. It extends 22km in a north south direction and the maximum width is 9km. The easterly projection of Wangi-Wangi Point, and the western sandy shallows from Swansea divide the lake into two natural parts. The lake was formed by the inundation of coalescing river valleys, but the ocean entrance which was initially much wider is now narrow and shallow due to sand deposition (Baas Becking *et al.*, 1959). Roy (1984) considers that the lake represents a youthful stage of a barrier estuary with characteristic rocky and highly irregular shoreline. The average depth of

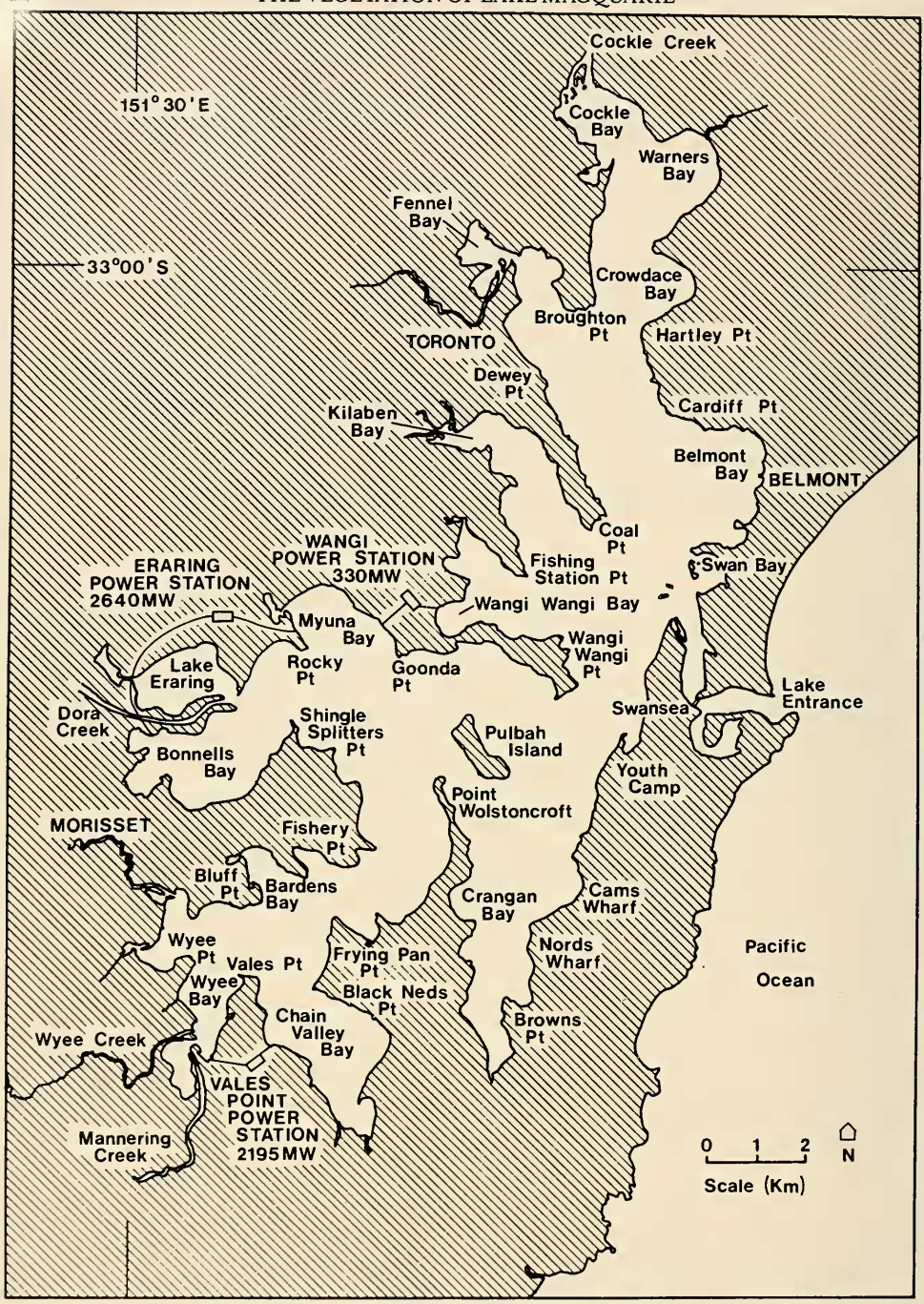

Fig. 1. Lake Macquarie, showing localities mentioned in the text and position of power stations.

the lake is 6.7m with a maximum depth of 11m east of Pulbah Island. At the entrance the spring tidal range is 1.25m but at the western end of the entrance channel it is only 0.15m. Average tidal range in the lake is only 6mm (State Pollution Control

Commission, N.S.W., 1983) and wind-induced currents are more important in producing water level changes (Roy and Peat, 1975). It is estimated that only one per cent of the lake volume is exchanged on each tidal cycle (State Pollution Control Commission, N.S.W., 1983) and salinity levels are thus highly dependent on catchment run-off and the flushing action of storm flows. Salinity is usually in the range 25-33.

Previous Studies

The seagrass communities of Lake Macquarie were first discussed in relation to an alleged depletion of fish (Wood, 1959a; MacIntyre, 1959). The former dealt with the seagrasses in only two pages and included a single map (scale approx. 1:180,000) showing the distribution of seagrasses within the entire lake. The latter made some cursory comments on seagrasses in relation to the benthic macrofauna. Since that time there have been a number of unpublished reports dealing with the seagrass distribution in various parts of Lake Macquarie, and often with specific reference to faunal community structure (State Pollution Control Commission, N.S.W., 1983). The only publications since Wood (1959a) surveying the total lake are those of Evans and Gibbs (1981) and West *et al.* (1985). Both surveys were based on aerial photographs.

The aim of the present study is to provide a detailed set of maps showing the present (1985) distribution and composition of the seagrass beds within Lake Macquarie with an indication of the relative contribution of the various species.

Methods

The lake was surveyed during late February/early March (1985). Observations on the extent, pattern of cover and species composition of seagrasses were made by use of transects run perpendicular to the shoreline at intervals of 50-200 metres, depending on the uniformity of the vegetation. The transects were extended until the deepest limit of the vegetation was reached, or in some cases were continued to the opposite shoreline. The methods of observation included direct viewing from a boat, raking with a long-handled rake, snorkelling, and wading in very shallow areas. The methods used at any site depended on turbidity and depth. The distance from the shore was measured using a rangefinder [Rangematic MK5: Ranging Inc. for distances over 50m (accuracy 99% at 100m, 95% at 500m, 90% at 1000m) and a Ranging Optimeter 620 for shorter distances].

The distribution of seagrasses was plotted on maps at an initial scale of 1:25,000. Two subjective scales were used: a scale of abundance and a measure of growth or sociability. Each scale has three categories:

Abundance 1. Sparse growth ($<$ 15% cover); 2. Moderate growth (15-50%); 3. Abundant growth ($>$ 50%).

Sociability: a. individual strands or clumps; b. patches of growth up to 10m; c. beds of relatively even distribution.

Thus the designation of a weed bed as Z1aH2c indicates a mixed bed of *Zostera* (sparse in individual strands or clumps) and *Halophila* (moderate growth and relatively evenly distributed). The area covered by weed beds was measured from enlarged copies of the maps using an *Apple 2E* microcomputer coupled to a graphics tablet.

Results and Discussion

This paper provides the basic distribution of seagrasses in Lake Macquarie in Summer 1985.

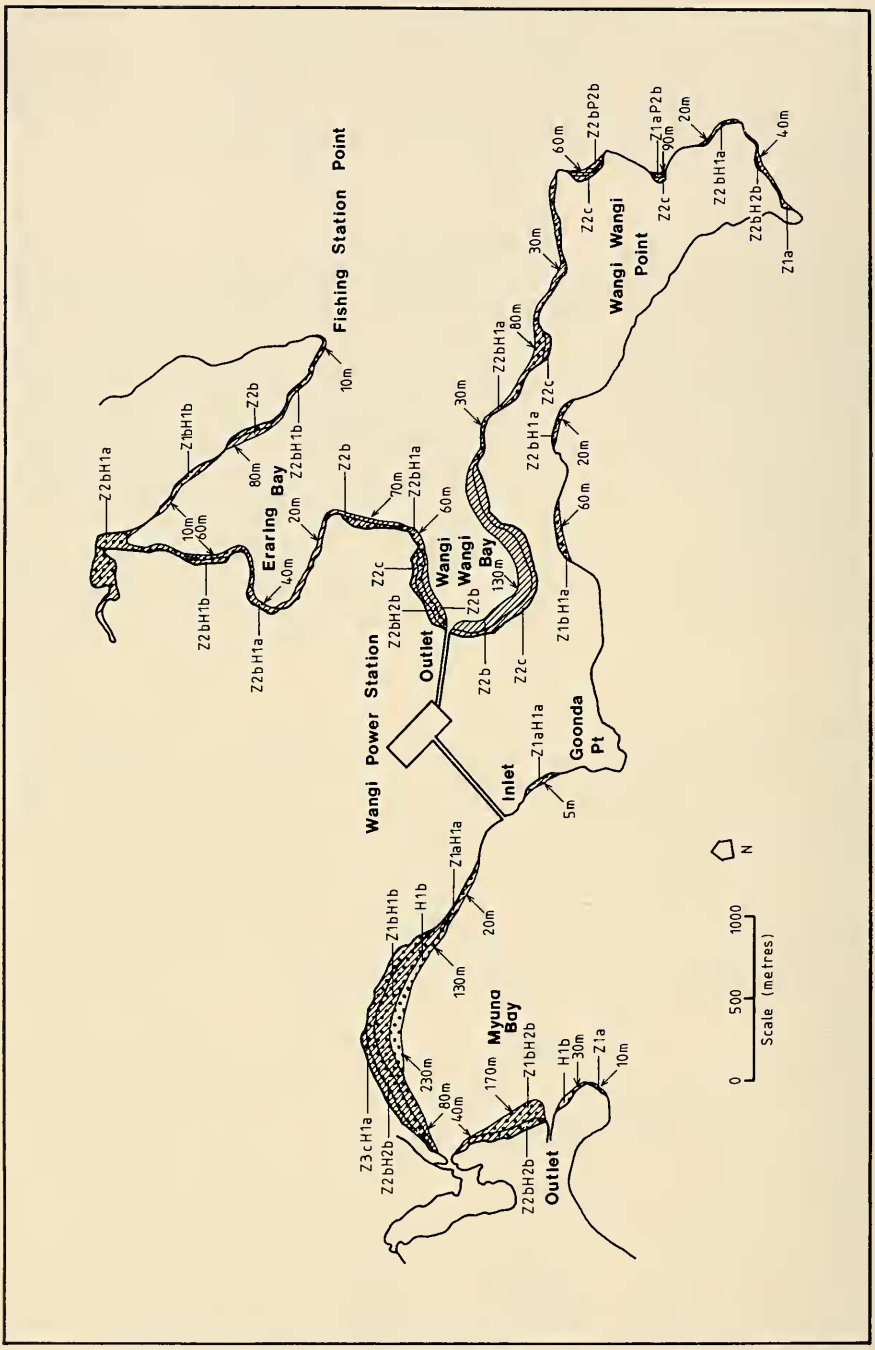

Fig. 2. Distribution of seagrasses in Lake Macquarie: Fishing Station Point to Rocky Point, western margin of lake.

Key to Figs 2-8:

Zostera *Halophila* *Ruppia* *Posidonia*

For key to abundance and sociability see text.

The results of the main survey are given in Figs 2-8. A full account of the survey is available in King (1986). The total area occupied by seagrass was 14.7km^2. The area occupied by each species, is presented in Table 1 along with information for the major regions and bays in the lake.

The magnitude and predictability of seasonal change and differences from year to year are discussed in King and Hodgson (1986). The data give some indication of the relative abundance of each species. For *Zostera capricorni* this information can be converted to estimates of total and above ground biomass (King and Barclay, 1986).

TABLE 1

Areas (km^2) of seagrasses in Lake Macquarie, survey of January-February 1985

	Reference figure	*Zostera*	*Halophila*	*Posidonia*	*Ruppia*	Total
Lake Macquarie (all areas)[1]		11.57	5.59	2.01	0.15	14.17
Myuna Bay (Eraring Outlet – Goonda Point)	2	0.25	0.29	–	–	0.29
Goonda – Fishing Station Point	2	0.47	0.26	0.01	–	0.48
Northern Lake (Fishing Station Point – Cardiff Point)	3 & 4	1.30	0.46	–	–	1.58
Central eastern (Cardiff Point – 'Youth Camp')	3	3.69	0.52	1.67	–	5.10
Crangan Bay ('Youth Camp' – Pt Wolstoncroft	5	1.05	0.31	0.02	–	1.07
Chain Valley Bay (Frying Pan Point – Vales Pt)	7	1.21	1.22	–	0.15	1.25
Wyee Bay inc. Mannering Bay	7	0.16	0.83	–	–	0.83
Wyee Point – Bluff Pt	7	0.62	0.60	–	–	0.74
Bonnells Bay (Shingle Splitters Point – Rocky Point)	8	2.00	1.08	–	–	2.00

[1]total includes several small areas not listed separately

There are three major species of seagrass in Lake Macquarie:
Zostera capricorni Ascherson is the only species of *Zostera* present. References by Wood (1959a) to *Z. muelleri* in Lake Macquarie are incorrect and result from the fact that Wood (1959b) did not appreciate the wide phenotypic variation which occurs in *Z. capricorni* (see Robertson, 1984).
Halophila ovalis (R. Brown) Hooker f.
Posidonia australis Hooker f.
In addition, the salt-tolerant genus *Ruppia* has been recorded.
Following Jacobs and Brock (1982) this material is referred to *R. megacarpa* Mason.

Zostera capricorni was the most widely distributed and abundant of the seagrasses in Lake Macquarie. It covered 11.57km^2 or 10 per cent of the lake area either in monospecific stands, or mixed with other seagrasses. *Halophila ovalis* occurred in 25% of the area of *Zostera*. The largest *Zostera* beds are in Belmont Bay and the areas just south of the entrance. Only 12 per cent of *Zostera* occurs in the northern half of the lake. The values

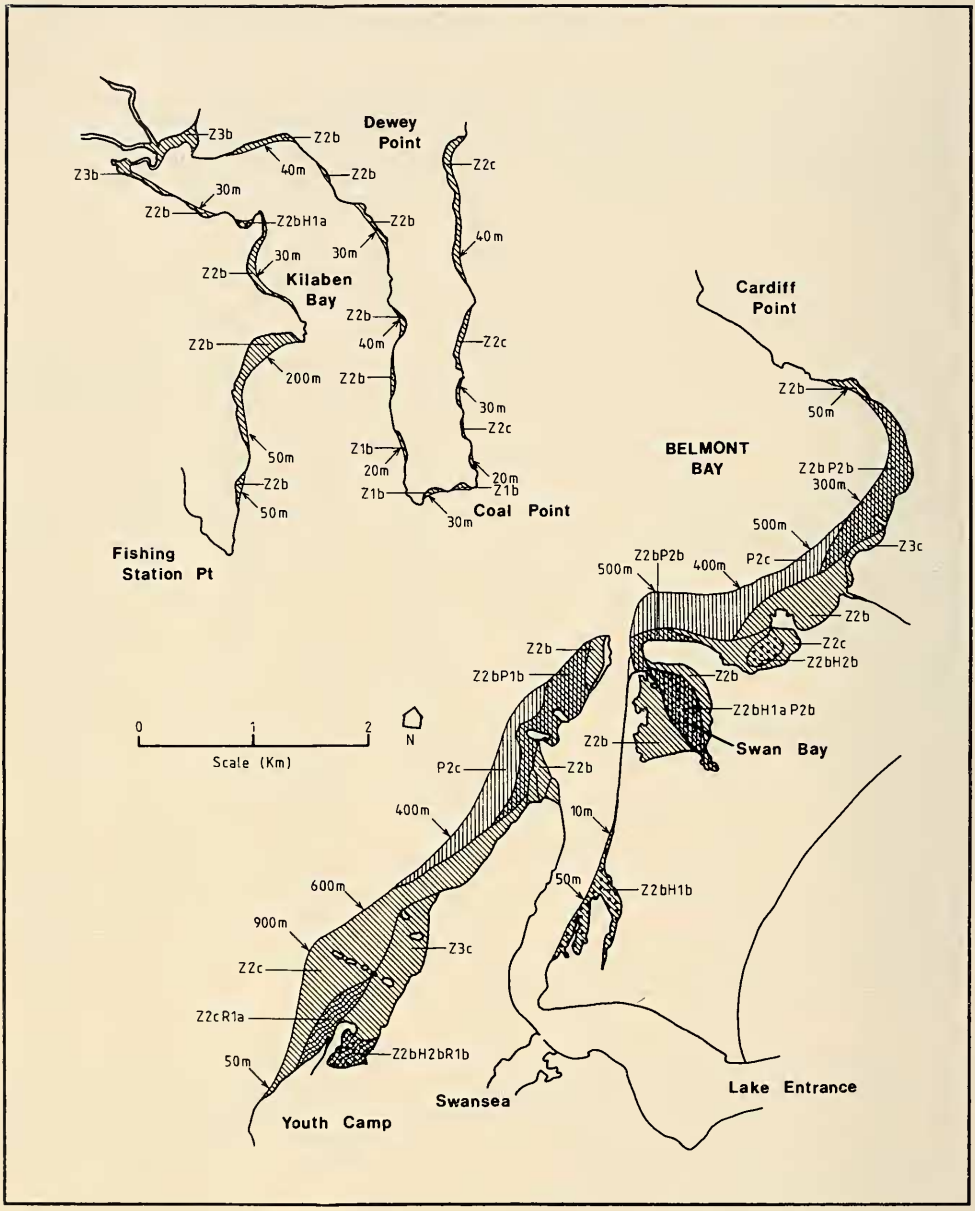

Fig. 3. Distribution of seagrasses in Lake Macquarie: central region of the lake: western margin (Dewey Point to Fishing Station Point); eastern margin (Cardiff Point to 'Youth Camp'). For key see legend to Fig. 2.

obtained in this study are comparable with data from West *et al.* (1985) and Evans and Gibbs (1981) (Table 2). In the latter study the total for all seagrasses was greater than in the present study but the area occupied by *Zostera* was estimated to be 12.24km^2, cf. 11.57km^2 here.

TABLE 2

Comparison of the areas of seagrasses in Lake Macquarie with values recorded in published surveys

Reference	Time of survey	Area of seagrass (ha)	Percentage of lake area[1]
Wood (1959a)	August 1953	2331	20
MacIntyre (1959)	August 1953	2548	22
Evans and Gibbs (1981)[2]	Aerial photographs: Nov., 1971; May, 1975 Field surveys: May, 1978	1788	15.5
West *et al.* (1985)	Aerial photographs: June, 1981 and March, 1982 (West, pers. comm)	1339	11.6
Present study[3]	Feb.-March (1985)	1417	12.3

Notes

1 Various estimates of lake area are available. Values calculated here are based on a mapped water area of 11511ha (West *et al.*, 1985).

2 Areas quoted for Lake Macquarie in Evans and Gibbs need to be increased by a factor of four (P. Gibbs; pers. comm). This correction has been applied to figures in the table above.

3 Lake Eraring was not included in this study but is included in all the other studies.

Halophila ovalis occurred over an area of 5.59km^2 often intermixed with *Zostera*. It was most common in shallow bays and especially in Mannering Bay and the southern end of Wyee Bay where it formed substantial monospecific beds. Evans and Gibbs (1981) reported only 0.55km^2 of *Halophila* in the lake but given the nature of their survey using aerial photographs it is likely that mixed beds were recorded as *Zostera* only, since the *Zostera* dictates the overall appearance of the beds. Wood (1959a) considered that *Halophila* was never in sufficient quantity to make it an important member of the seagrass community, a conclusion which is contradicted by the results obtained here.

Posidonia australis has a limited distribution and covered an area of only 2.01km^2, some 1.67km^2 on the eastern shore near the lake entrance. This compares with a total area of 0.53km^2 recorded by Evans and Gibbs (1981). It occurred alone in patches or beds of relatively even distribution offshore from *Zostera* and mixed *Zostera/Halophila* beds, with which it was sometimes interspersed (Fig. 3). There were small isolated patches of *Posidonia* in Crangan Bay just south of Cams Wharf; on the east side of Pulbah Island; and on the western lake shore of Wangi-Wangi Point.

Ruppia megacarpa was recorded in only 0.1km^2 in Chain Valley Bay, though Wood (1959a) showed *Ruppia* to be the dominant seagrass in backwaters (Mannering Bay and the southern portion of Chain Valley Bay) as well as the flats to the west of Swansea. The abundance of *Ruppia* shows great fluctuations in other coastal saline lagoons such as Smiths Lake and Tuggerah Lakes and this aspect is discussed in detail in King and Hodgson (1986).

In addition to aquatic angiosperms, benthic algae, especially *Gracilaria verrucosa* (Hudson) Papenfuss, *Microdictyon umbilicatum* (Velley) Zanardini and *Cystophyllum onustum* (Mertens) J. Agardh, may be locally abundant.

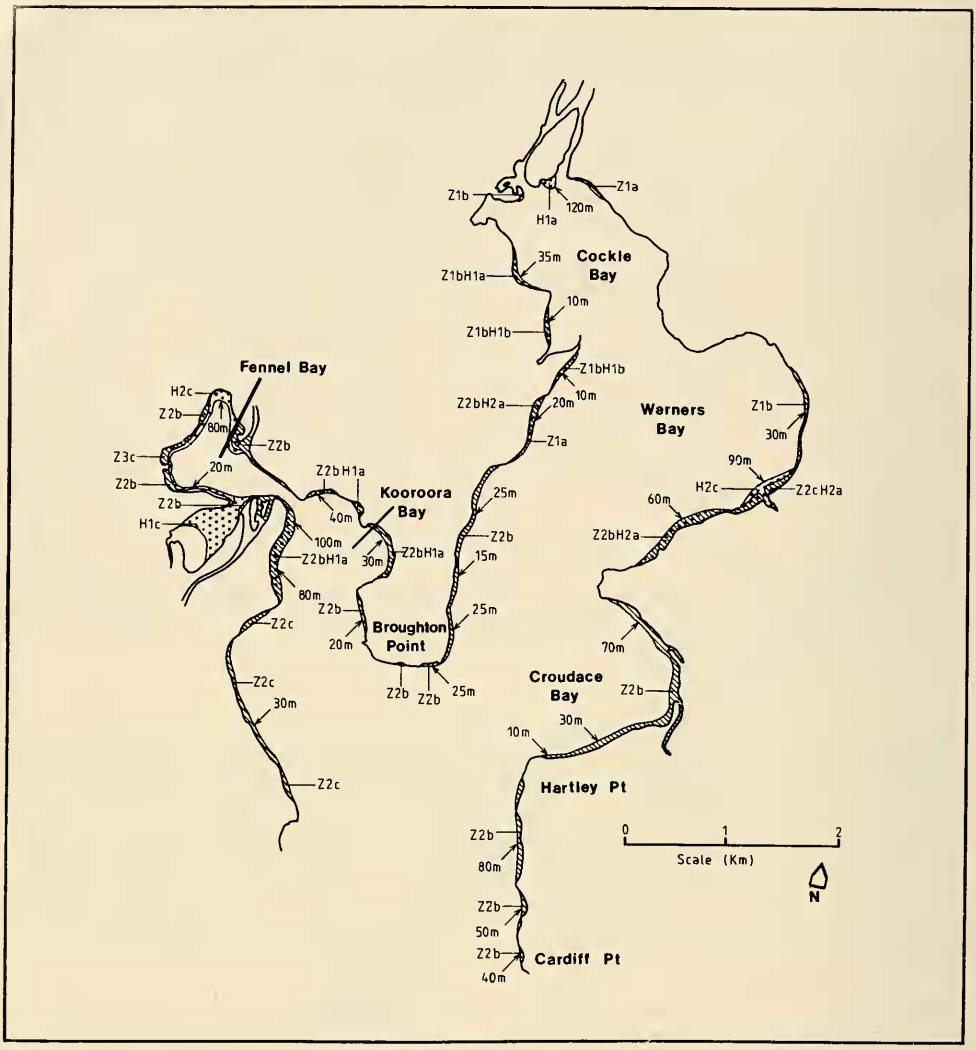

Fig. 4. Distribution of seagrasses in Lake Macquarie: northern portion of the lake (Dewey Point to Cardiff Point). For key see legend to Fig. 2.

The method of survey adopted in this study has proved to be very satisfactory for broad scale vegetation mapping and estimations of abundance. It has several advantages over mapping from aerial photographs:

- the surveys can be undertaken at an appropriate time, e.g. at the time of maximum biomass rather than based on photographs generally taken for some other purpose;
- species and mixed-species populations can be recognized at the time of survey, and hence changes within small areas will be recorded;
- measures can be made of species abundance as well as distribution. The scheme of recognizing three levels of abundance and three levels of sociability is far simpler than, for instance, a direct Braun-Blanquet type scale of 0-9 of the type used by Kirkman (1978). This is especially so where comparable results are required from different field workers.

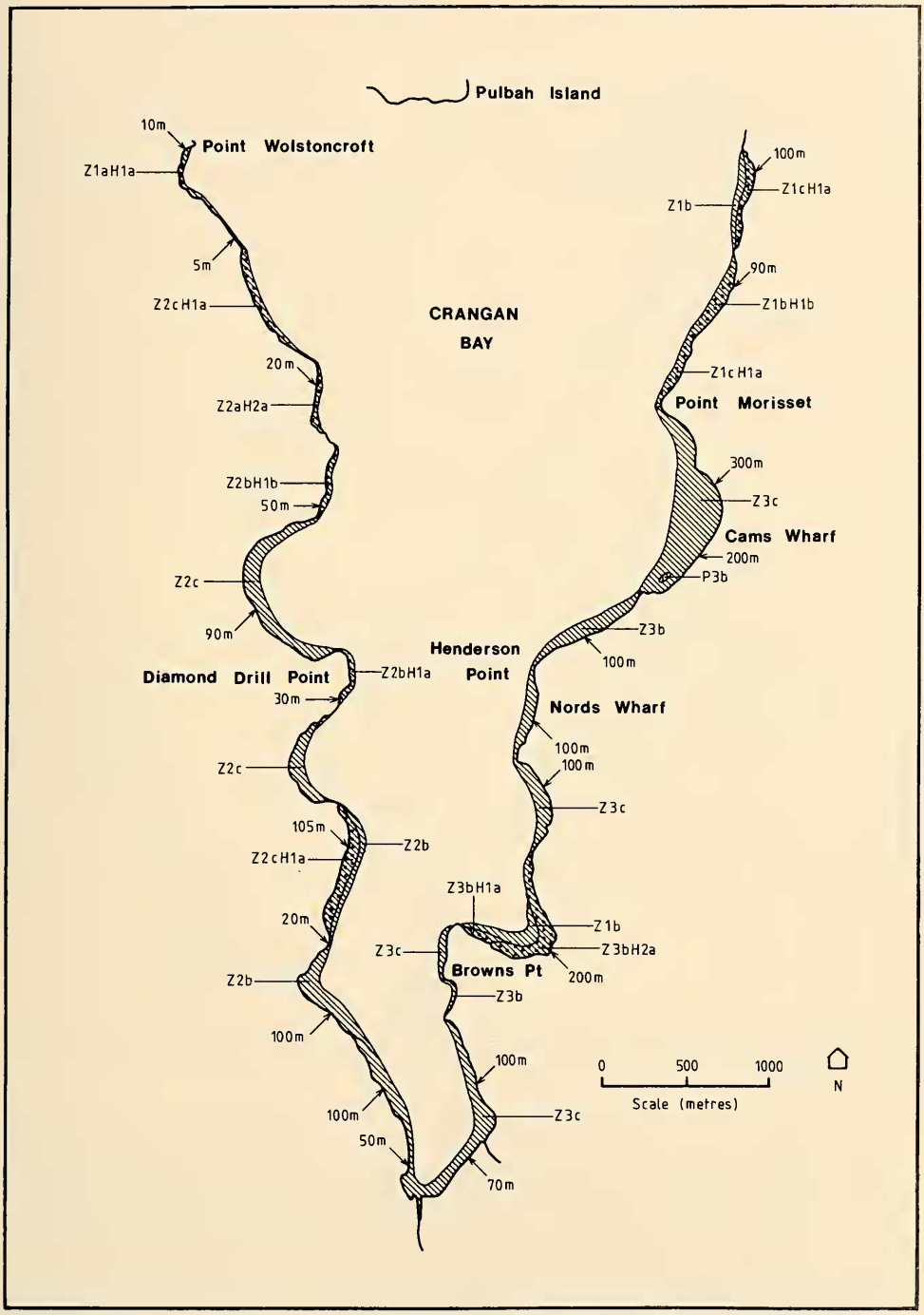

Fig. 5. Distribution of seagrasses in Lake Macquarie: southeastern section (Crangan Bay). For key see legend to Fig. 2.

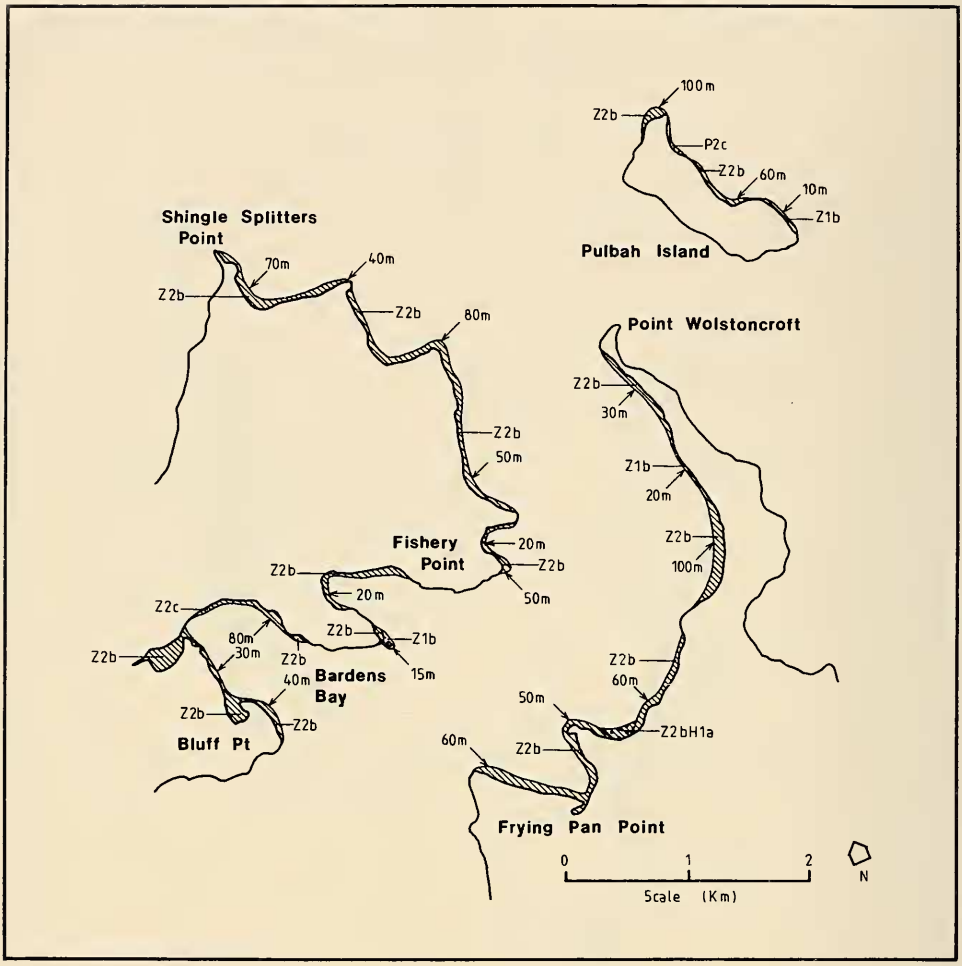

Fig. 6. Distribution of seagrasses in Lake Macquarie: southern region of the Lake (Point Wolstoncroft to Frying Pan Point and Bluff Point to Shingle Splitters Point). For key see legend to Fig. 2.

- since the accuracy of the final estimates of area occupied by seagrass is ultimately dependent on the scale of the original maps, this type of survey can be much more accurate. For example reading areas from maps of the scale of that in Wood (1959a) is impossible, even assuming that the map itself is reasonably accurate. The problem is compounded by the difficulty of measuring in areas where the seagrasses occur as narrow fringing beds. The provision of the absolute values for the width of the beds as in the present survey can be useful for later detailed comparisons in specific areas.
- the scale or intensity of the survey can be readily adapted to suit specific requirements of the user.

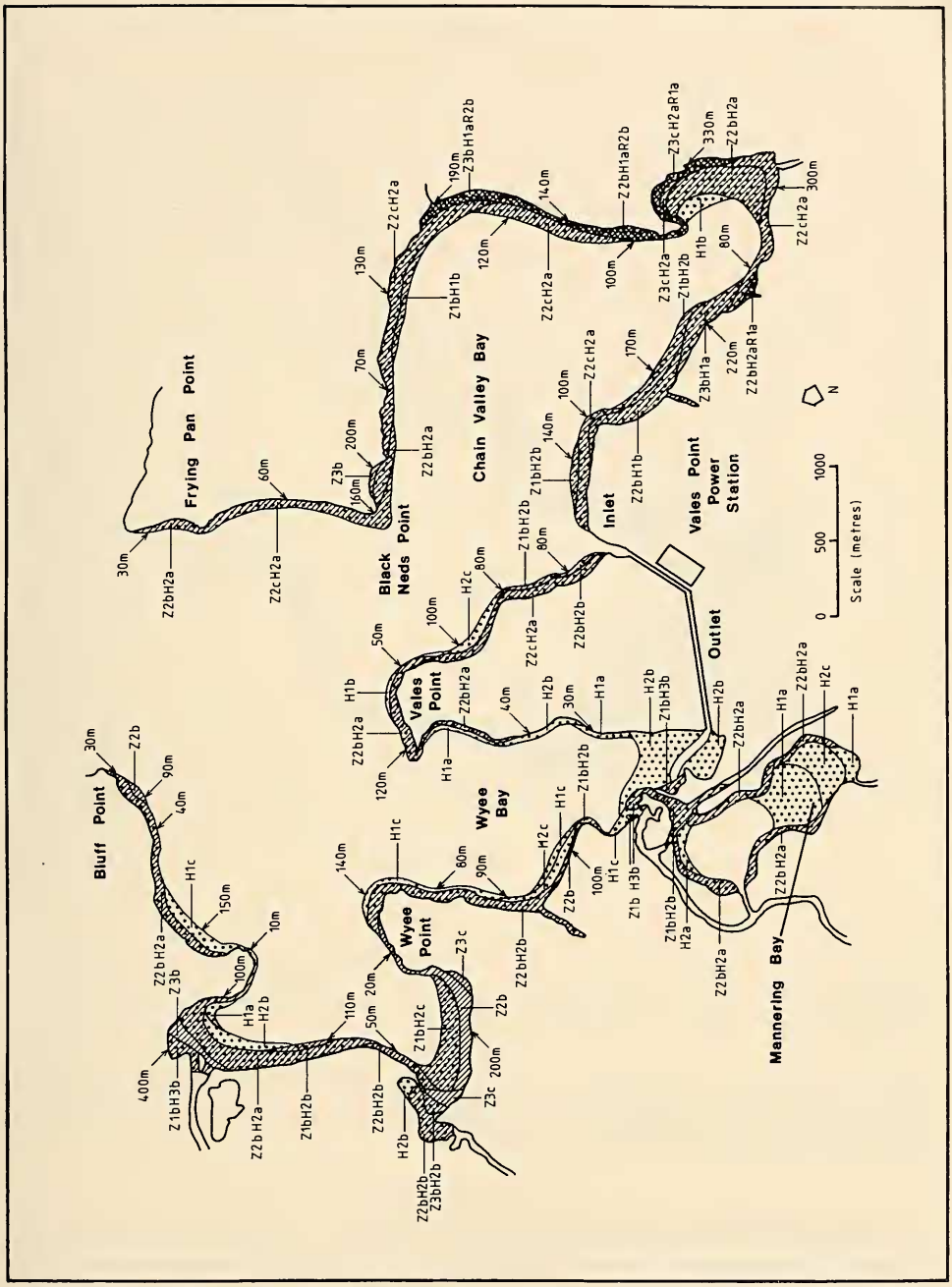

Fig. 7. Distribution of seagrasses in Lake Macquarie: southwestern portion of the lake (Wyee Bay and Chain Valley Bay). For key see legend to Fig. 2.

The methods adopted for surveys of seagrass beds will depend on the use to which the data will be put. Data to provide a base-line against which future change might be measured should be at least as detailed as this method allows. However there are still considerable problems with interpretation of changes over time (King and Hodgson,

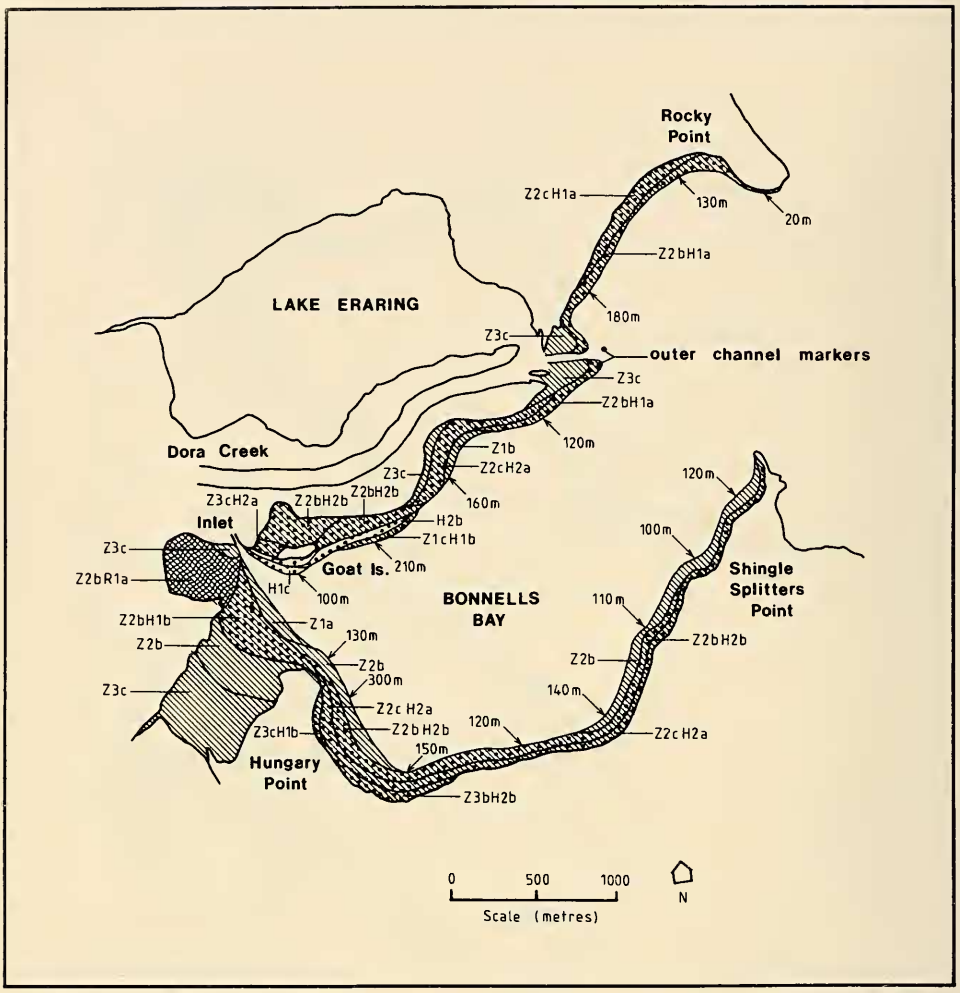

Fig. 8. Distribution of seagrasses in Lake Macquarie: western portion of the lake, Bonnells Bay (Shingle Splitters Point to Rocky Point). For key see legend to Fig. 2.

1986). The major disadvantage of the method used here is that it is time consuming. Hence it would be inappropriate to the provision of a broad scale inventory of seagrass resources of the type provided by West *et al.* (1985).

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